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A New Dynamic Assessment for Multi-parameters Information of Water Inrush in Coal Mine*

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Abstract

The coal mine flood is one of five nature disasters in the mine construction and production process. During the past 20 years, more than 250 mines were flooded, and the direct economic losses reached as high as more than 350 hundred million Yuan. In this article, the regional arrangement of sensors in the face of the program, considering the water level roadway, aquifer water levels, the top and bottom side pressure and the amount of water before driving and other factors, in combination with hydro-geological information and monitoring data, based on BP neural network and DS theory of levels of evidence coal face integration evaluation model of water bursting. It has been carried on the example analysis in the ore 3# coal bed in Shanxi, the results of prediction in line with the actual results, and different conditions for many parameters of the mine statistics, storage and evaluation.

Keywords: Mine Flood; BP Neural Network; DS Theory; Multi-parameters

1. Introduction

Water blood is common disaster in coal mines. Explore coal mine water flood mechanism, seek the technology of from passive treatment to active control are an important element in the mine job. The impact factors of mine water inrush are various, mine water inrush result of many effect factors. However, it is difficult to use precise mathematical language to describe the mechanism of mutual effect between many effect factors [1].

At present, the common methods used at home and abroad can be divided into four categories:

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geological assessment analysis, mathematical and computer model evaluate analysis, geophysical exploration evaluate analysis and water chemistry plasma and isotopic evaluate analysis. However, many reasons like single method and equipments are not enough advanced make lack of effective dynamic monitor tools in the process of coal mine normal exploit. In this article, at the basis of geological prospect, applied the automatic detection and multi-sensor data fusion technology for coal mine water disaster prevention and strengthened the dynamic monitor in exploit process [2,3].

2. The design of face water inrush dynamic evaluation mode

Mine water inrush is in the specific hydro geological conditions, impermeable rock happened deformation and damage under the combined effect of outside pressure and confined water, resulted in the confined water influxed into mining space. At the same time, different geological environment in coal mines, rocks nature, the size and distribution of stress, different faults, as well as the development of fracture zone probably induced mine water inrush of different mechanism. Therefore, the mine water inrush is caused by a combination of many factors, and various factors have a strong non-linear relationship. The evaluation of coal water inrush requires a self-adaptive, self-study and dynamic nonlinear treatment method objectively.

Artificial neural network with self-learning and adaptive capacity, it can analysis the correspond input-output data provided in advance and master the potential law between them, and ultimately basis of these laws, with new input data to project the output results[4]. Applied artificial neural network technology into mine water inrush prediction is used its unique advantages in solve of non-linear or non-structural problems. To the water inrush prediction neural network, as long as there is a certain amount of process water sample, then the network will be able to establish the mapping relationship between mine water inrush and every kind factors through the training process, then used them into mine water inrush prediction[5] .

Because the output of the single neural network is instability, sometimes the output have deviation. Therefore, put forward applied the fusion method combined of D-S evidence theory and BP neural network to the mine water inrush systematic evaluation model, namely use BP neural network distribute basic probability for the D-S theory of evidence. Its information fusion treatment and system evaluation security level as shown in Figure 1[6].

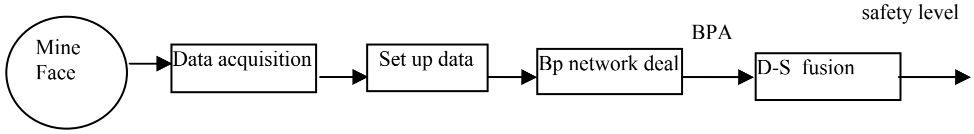

Fig.1 Coal face dynamic evaluation system diagram

2.1 Determine the main factors impact work face water inrush

The formation of water inrush from coal face is very complex, involving hydrological, geological structure, the impact of mining elements[7]. Therefore, set up water inrush evaluation model required a comprehensive analysis related factors of the mine face water inrush. After discussed with hydro geological experts, propose the main factors caused the mine work face water damage: the pressure of the roof and floor, the aquifer water level of bottom, water level of roadway and the driving side of the water before the job.

2.1.1 Sensor layout and parameter measurement

In this article, working underground at the region, in accordance with the conditions of the geological structure at the scene, at roof, floor and roadway layout with the appropriate sensors, top and bottom pressure sensors, liquid level sensors for the roadway in order to carry out many dynamic water parameter measurements. Detection of the main roof is fractured sandstone roof water, bottom water is mainly Ordovician limestone water, tunneling refers to the process of major goaf water stagnant water and the old kiln.

Before heading to the advanced detection of water, using more advanced current transient electromagnetic method. Mine transient electromagnetic method developed in recent years in the coal mine tunnel in space exploration around the different locations, different forms of water-bearing structure of the mine geophysical methods. In coal mining before the detection by this method, you can determine the electric underground geological body, and the size of such occurrence.

These factors constitute a 5-dimensional model (the number of water inrush factor 5 in the model, that is N = 5) input vector, and the output of the model is the safety level of water inrush S = (S1, S2, S3, S4). S1 is safety, S2 safer, S3 general, and S4 dangerous. Model structure in Figure 2, the number of hidden layers, each hidden layer neuron number can be selected according to actual needs.

2.2 Set up sample database and the normalize treatment of sample data [8]

After determined the water inrush impact factors, we can set up model sample database in accordance with these factors, such as drilling a water aquifer, the pressure of coal mine roof and floor have specific data, they can be directly import into the database, the roadway level, flow and side of the water before heading must be accumulated in the actual process, gradually establish a comprehensive samples and data database. Various factors affect the water inrush are the field in database, and every mine water inrush cases, face safety mining or roadway safety tunnel examples is a record in the database.

Mining, sounding data adopted 6 groups points have been taken as a sample to build prediction model, each sample includes 5 areas information (the top and bottom pressure, the water level roadway, the aquifer's water, and the amount of water before driving), organize storage in the sample database. Level of water burst security position 4 class, S1class: 0.1，0.1，0.1，0.9; S2 class: 0.1，0.1，0.9，0.1；S3 class: 0.1，0.9，0.1，0.1; S4 class: 0.9，0.1，0.1，0.1.

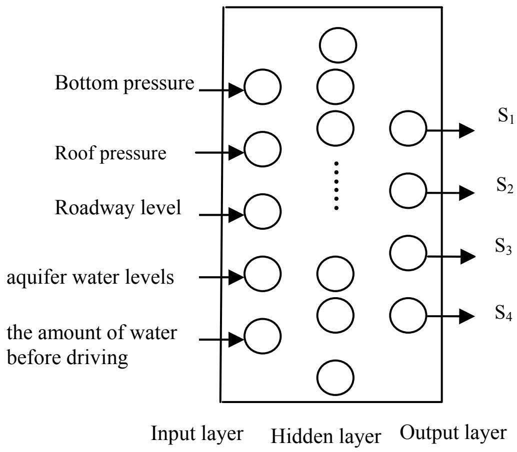

Fig.2 Water inrush evaluation BP neural network model

2.3 BP neural network set up

2.3.1 Generate of Neural network

Before training the neural network requires structure a network framework, function newff () is structure neural network. It needs four input conditions were: the R × 2 dimensional matrix constitute from the largest minimum value of R-dimensional input samples, the number of every layers` neurons, each neuron transfer function, as well as the name of training function.

2.3.2 Weight initialization

BP neural network must to initialize weights and threshold value before training, newff () function can automatically finish the process, but it can not re-enabling the initial value. Init function can be used to initialize the network to restore the situation.

TABLE 1 water inrush training sample

Number	Roof pressure (Mpa)	Bottom pressure (Mpa)	aquifer water levels (cm)	Roadway level (cm)	the amount of water before driving (m^3/h)	safety level
1	2	4.2	640.2	48.2	10.2	S_1
2	2.5	5.2	641.4	46.3	9.8	S_1
3	3.0	6.2	639.1	47.3	6.3	S_2
4	6.1	7.8	660.1	50.2	11.2	S_4
5	5.2	6.3	670.1	71.2	8.4	S_3
6	2.7	4.9	642.5	48.5	7.6	S_1

2.3.3 Network simulation

After given network structure and input variables, use sim() function calculate correspond network output.

2.4 D-S theory of evidence

D-S algorithm is a proof reasoning algorithm based on the evidence demonstration, it was proposed by Dempster firstly, then developed and expanded by Shafer, called the D-S theory of evidence. It does not need a priori information, use "interval estimation" rather than "point estimate" to describe the uncertain information, it solved the uncertainty expression method about "unknown", it shows that a great deal of flexibility in the distinction did not know and uncertainties, as well as accurately reflect the collection of evidence.

2.4.1 The principle of D-S theory of evidence [10]

D-S theory of evidence be applied to the prediction of mine water hazard, D-S theory of evidence is the fusion based on the basic probability assignment, it turned the impact of each sensor to goal status into a probability to calculation, D-S theory of evidence synthesis formula as follows:

$$m(A) = \frac{1}{1-k} \sum_{Ai \cap Bj \cap Ck \cap ... = A} m_1(A_i) \bullet m_2(B_j) \bullet m_3(C_k) ...$$

$$k = \sum_{Ai \cap Bj \cap Ck \cap ... = \Phi} m_1(A_i) \bullet m_2(B_j) \bullet m_3(C_k) ...$$

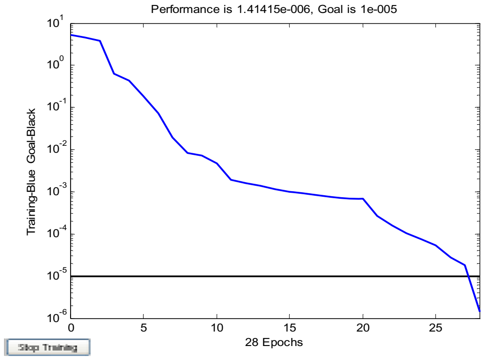

Fig.3 BP1 network training performance

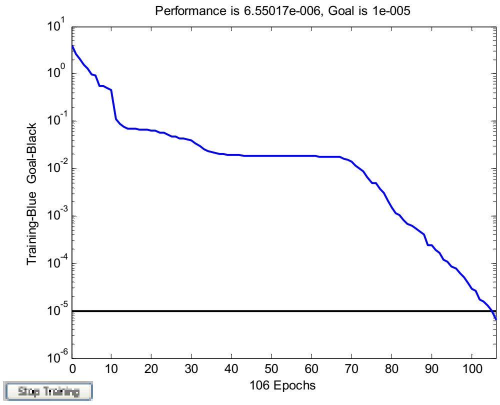

Fig.4 BP2 network training performance

The size of k reflects the degree of evidence conflict. Coefficient 1 / (1-k) as the normalization factor, it is the role of avoid in order to put non-zero probability to empty set when synthesis.

The synthesis formula of n-source evidence are defined as follows[9]:

$$m(A)=\frac{1}{1-k}\sum_{Ai\cap Bj\cap Ck\cap ...=A} m_1(A_i)\bullet m_2(B_j)\bullet m_3(C_k)... \quad k=\sum_{Ai\cap Bj\cap Ck\cap ...=\Phi} m_1(A_i)\bullet m_2(B_j)\bullet m_3(C_k)...$$

2.4.2 Improved synthesis formula

For the above formula, when k = 1 will not be able to use, because the denominator is zero at this time. And when k→1, that is, evidence in high degree conflict, the formula would be get the result of violate common sense.

In view of this, Yager improve the synthesis formula of D-S, improved formula is as follows (two sources of evidence).

$$m(\phi)=0$$

$$m(A)=\sum_{A_i\cap B_j=A} m_1(A_i)\cdot m_2(B_j),\quad A\neq\phi,\quad X$$

$$m(X)=\sum_{A_i\cap B_j=X} m_1(A_i)\cdot m_2(B_j)+k$$

Removed the normalized factor 1 / (1-k), and reflects the degree of conflict k was assigned to $m(X)$ after synthesis.

3. Case study

According to national coal mine peaceful concerned requirements, for the victims areas affected by the threat of water, adhere to the "exploration must have suspected, after the first dig into" principle. Before roadway tunnel use drill, geophysical method such as geological conditions. According to the hydro geological conditions, combined with the data get from a number of points neural network and the D-S evidence theory to predict and recommend preventive measures.

Use MATLAB program to set up BP neural network, BP algorithm have some disadvantages that is, slow convergence, local maximum, it is difficult to determine the hidden layer and the number of hidden layer nodes. In this paper, BP algorithm fail up to accurate, after several tests finally determined by quasi-Newton algorithm. Quasi-Newton algorithm have faster convergence, especially for the higher dimension of the problem has obvious advantages.

The output of a single BP network instability, this paper use two BP networks formation as two BPAF as evidence input, through D-S evidence theory's combination rules to calculation. The data correlation between then is small, you can consider the output results are independent of each other. Because of nerves and measure data have errors, use the square of neural network and errors function (SSE) value to express the uncertainty evidence.

The training function of BP1 network is trainbfg, the training function of BP2 network is trainlm, parameters relating to them set to the largest number of 300 (epochs), the training requires accuracy of 10-5 (goal), shows training iterative process 10 (show).

Use the BP1, BP2 neural network after training its correspond output, and normalized the output of BP1, BP2, that is, formation the evidence of evidence theory. Then in accordance with the D-S evidence rules to fusion, and its output as shown in table 2.

TABLE 2 fusion result

number	target	Fusion method	S_4	S_3	S_2	S_1	$m(\theta)$
Validation Sample 1	S_1	BP1	0.0810	0.0838	0.0819	0.7533	0.0205
		BP2	0.0841	0.0818	0.0823	0.7513	0.0086
		D-S fusion	0.0145	0.0150	0.0146	0.9906	0.0003
Validation Sample 2	S_2	BP1	0.0825	0.0843	0.7500	0.0832	0.0045
		BP2	0.0833	0.0833	0.7500	0.0833	0
		D-S fusion	0.0124	0.0126	0.9646	0.0125	0

4. Conclusions

From Table 2 can be seen that although the evaluation results of BP1, BP2 to sample 1 and sample 2 are right, but can be seen from the experimental results, through the D-S evidence theory fusion uncertainty greatly reduced, to sample 1 as an example, the uncertainty of BP1, BP2 are 0.0205 and 0.0086 respectively, after the integration the uncertainty reduced to 0.0003. Through the two-grade fusion significantly improve the accuracy of determine security status of the mine, and relatively in line with actual data.

The completion of the evaluation model is built on the foundation of many factors that water inrush, the reliability of the conclusions that the system given are directly related with the accuracy and full extent of the information user provided. For those informative and comprehensive mining area, the user can take full advantage of this evaluation model, get more precise conclusions. For those temporarily unable to obtain additional information requires place sensors in accordance with the actual terrain first, then accumulate measured data of the day, month, year, set up a comprehensive database of samples and data. Re-use this evaluation model to predict evaluation the water inrush status.

References

[1] Zhang yingmei, Tang hongying, "Research on Application of Virtual Instrument in Coal Mine Pump Control System," Coal Mine Science and Technology, 2008(2),pp.68-71.(in Chinese)

[2] Mao hongchuan, Liu zhi, Deng chuntao, Wang dangliang, "Evaluation Method of mine water inrush," Hebei Science and Technology,2008,25(4),pp.197-199. (in Chinese)

[3] Dubois H. representation and combination of uncertainty with belief functions and possibility measures, Computational Intelligence, 1998,(1):pp.88-101

[4] Zhang yonghuai, Liu junhua, "Use neural network and improve algorithm to improve the sensor characteristics," Journal of sensor technology，2002(9). (in Chinese)

[5] Zhang yingmei, Cheng zhenzhen, "The Coal Mine Flood Prediction Research Based On Neural Network and D-S Theory of Evidence," IEEE IITA, 2008(12),pp.311-315. (in Chinese)

[6] Wu jinglong, Wang ju, Wang chunshan, "The application of artificial neural network system in the coal mine water inrush," Coal Mine Safety,2008(4) .(in Chinese)

[7] Jiang chengzhi, Zhang shaobing, "Mine water inrush evaluation model based on the neural network," Journal of Heilongjiang Institute of Science and Technology, 2006, 116(1): pp.9-11. (in Chinese)

[8] Dong shuning, Jin dewu, Feng an, "The prevention and control of coal water utility technology and equipment," Coal Science and Technology，2008,36(3):pp.8-11. (in Chinese)

[9] Yager R R, "On the Dempster-Shafer Framework and New Combination Rules," Information Science, 1998(4): pp.93-138

[10] Zhang yingmei, Cheng zhenzhen, "The Application of D-S evidence Theory In coal mine flood prediction," Journal of Taiyuan University of Technology, 2008(11),Vol.39No.6. pp.589-591.(in Chinese)